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IS 9793-1-1 to 3 (1982): Antennas for the Reception of Sound and Television Broadcasting in the Frequency Range 30 MHz to 1 GHz, Part 1: Methods of Measurement (Sections 1-3) [LITD 7: Audio, Video and Multimedia Systems and Equipment]

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भारतीय मानक

आवृति रेंजों में ध्वनि और दूरदर्शन प्रसारण के अभिग्रहण के लिए एन्टीना — विशिष्टि 30 मेगाहर्ट्ज से 1 गेगाहर्ट्ज तक

भाग 1 मापन पद्धतियां

अनुभाग 1 विद्युत एवं यांत्रिक लक्षण

अनुभाग 2 विद्युत कार्यकारिता प्राचलों की परीक्षण पद्धतियां

अनुभाग 3 यांत्रिक गुणधर्म और पर्यावरणीय परीक्षणों की परीक्षण पद्धतियां

(पहला पुनरीक्षण)

Indian Standard

ANTENNAS FOR THE RECEPTION OF SOUND AND TELEVISION BROADCASTING IN THE FREQUENCY RANGE 30 MHz TO 1 GHz — SPECIFICATION

PART 1 METHODS OF MEASUREMENT

Section 1 Electrical and Mechanical Characteristics

Section 2 Methods of Tests of Electrical Performance Parameters

Section 3 Methods of Tests for Mechanical Properties and Environmental Tests

(First Revision)

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Radio Communication Sectional Committee, LTD 20

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Radio Communication Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

The object of this standard is to define and specify the essential electrical and mechanical characteristics and the relevant methods of measurement for antennas for the reception of sound and television broadcasting.

This standard was originally published in 1980 and is being revised now to bring it in line with the latest edition of IEC Pub 597 on which it was based. In this revision it has also been decided to cover the methods of measurements for antennas in three sections as given below:

Section 1 — Electrical and mechanical characteristics

Section 2 — Methods of measurements of electrical performance parameters

Section 3 — Methods of measurement of mechanical properties and environmental tests.

The methods of tests given in this standard are essential for guidance purposes. The users could as well use alternate well established methods if mutually agreed upon.

This standard is largely based on the following IEC Publications issued by the International Electrotechnical Commission:

IEC Pub 597-1 (1977)	Aerials for the reception of sound and television broadcasting in the frequency range 30 MHz to 1 GHz, Part 1 : Electrical and mechanical characteristics.
IEC Pub 597-2 (1977)	Aerials for the reception of sound and television broadcasting in the frequency range 30 MHz to 1 GHz, Part 2 : Methods of measurement of electrical performance parameters.
IEC Pub 597-3 (1983)	Aerials for the reception of sound and television broadcasting in the frequency range 30 MHz to 1 GHz, Part 3 : Methods of measurement of mechanical properties, vibration and environmental tests.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ANTENNAS FOR THE RECEPTION OF SOUND AND TELEVISION BROADCASTING IN THE FREQUENCY RANGE 30 MHz TO 1 GHz — SPECIFICATION

PART 1 METHODS OF MEASUREMENT

Section 1 Electrical and Mechanical Characteristics

(First Revision)

1 SCOPE

1.1 This standard (Part 1/Sec 1) applies to the linearly polarized receiving antennas for domestic use, in the frequency range 30 MHz to 1 GHz.

2 REFERENCES

2.1 The Indian Standard IS 1885 (Part 21/Sec 1 to 6) : 1988 is a necessary adjunct to this standard.

3 TERMINOLOGY

3.0 For the purpose of this standard, the following terms and definitions in addition to these covered in IS 1885 (Part 21/Sec 1 to 6) : 1988 shall apply.

3.1 Receiving Antenna

That part of a radio receiving system which effects conversion between intercepted electromagnetic waves and guided radio frequency currents or fields in an associated transmission line.

NOTE — This definition will normally include any impedance matching devices, baluns and integral active equipment integrated with the antenna.

It includes also those parts of the transmission line, supporting structure and other components which influence antenna performance by virtue of proximity, where they form part of the assembly as supplied or as required for the installation. These can be excluded from the specification if agreed between the purchaser and the manufacturer.

3.1.1 *Active Receiving Antenna*

An antenna which incorporates an active device as an integral part essential for its proper functioning.

3.2 Antenna Gain

The ratio expressed in decibels of the power delivered to the resistive load, specified in **3.1**, when the antenna is optimally oriented in the uniform field of a plane linearly polarized electromagnetic wave, to the power available from a correctly terminated half-wave dipole optimally orientated in the same wave field.

NOTE — The gain of an antenna may also be expressed as relative to an isotropic antenna expressed in dBi. The gain of a half-wave dipole compared with an isotropic antenna is theoretically 2·15 dBi.

Unless otherwise specified, the figure expressing the gain of an antenna refers to the gain in the direction of the main lobe. When the antenna has been designed to receive from a direction other than that of the main lobe, the direction for which the gain is given shall always be stated. The type of reference antenna, and whether the gain is expressed as numerical ratio or in decibels, shall be clearly indicated.

3.3 Directivity Protection

The ratio expressed in decibels, of maximum forward gain to the maximum minor lobe gain.

3.4 Cross-Polarization Protection

The ratio expressed in decibels, of the power received from a wave linearly polarized in the designed plane of polarization, to the power received from an orthogonally polarized wave of the same amplitude.

3.5 Half-Power Bandwidth

Angular width of the major lobe in both *E* and

H planes respectively, between points at which the gain is 3 dB below its maximum value.

3.6 Bandwidth

The extent of a continuous range of frequencies over which an antenna characteristic or performance parameter conforms to a specified value.

3.6.1 *Gain Bandwidth*

The frequency range over which the antenna gain does not vary by more than a specified amount.

3.6.2 *Directivity Protection Bandwidth*

The frequency range over which directivity protection does not fall below a specified value.

3.6.3 *Impedance Bandwidth*

The frequency range over which changes in an antenna terminal impedance do not increase the magnitude of the reflection coefficient or the standing wave ratio (SWR) at the antenna terminal above a specified amount.

3.6.4 *Cross-Polarization Protection Bandwidth*

The frequency range over which cross-polarization protection does not fall below a specified value.

3.6.5 *Operating Bandwidth*

The frequency range over which the specified gain, directivity protection, impedance and, when required, cross-polarization protection are all maintained within specified limits.

3.7 Power Surface Density (S)

Power transmitted per unit area of a surface normal to the direction of propagation of a plane electromagnetic wave. It is expressed in watts per square metre as a function of the electric field strength (E) in volts per metre, by the following equation:

$$S = \frac{E^2}{120\,\pi}$$

3.8 Terminal Devices

Means for providing connection between antenna and feeder.

3.9 Wind Load

Horizontal forces acting on the support mast caused by the wind resistance of the antenna.

3.10 Ice Load

Addition load on the antenna and supporting structure due to ice.

3.11 Transfer Standard Antenna

A reference antenna of a closely reproducible, specified construction, having a gain and directivity greater than that of a half-wave dipole, which can be determined by calculation and where necessary, confirmed by measurement, as being sufficiently consistent for use as a transfer standard for antenna gain measurements.

3.12 Directivity Pattern

The graphical presentation, at a certain frequency and in a specified plane, of the ratio between the output voltage (or current) of the antenna to the maximum output voltage (or current) in the same plane, as a function of the angle of rotation, when the antenna is placed in a uniform field. Since field strength is proportional to voltage (or current), this pattern is sometimes called a field strength directivity pattern. This may also be referred to as radiation pattern.

3.13 Antenna Impedance

The impedance at the terminal device.

3.14 Reflection Co-efficient

If the characteristic impedance of the antenna transmission line is equal to Z_0 and the antenna impedance is equal to Z_a, the reflection co-efficient r is given by:

$$r = \frac{Z_a - Z_0}{Z_a + Z_0} = (r)\ \exp (j\psi)$$

Z_0 shall be equal to the resistive load, according to **4.1**.

3.15 Return Loss Ratio (RLR)

The reciprocal of the magnitude of the reflection coefficient, expressed in dB and given by the formula:

$$A_z = 20 \log \frac{1}{(r)}$$

3.16 Standing Wave Ratio (SWR)

The ratio of the maximum to the minimum voltage in a loss-less line of characteristic impedance Z_0 connected to the antenna. It is related to the reflection coefficient r by the formula:

$$S = \frac{1 + (r)}{1 - (r)}$$

3.17 Feeder Pick-up

Transfer of signal power in the outer surface of the outer conductor of a coaxial transmission line, or unbalanced signal power in the conductors of a symmetrical transmission line, through an antenna terminal device into the transmission line as an interfering signal component.

3.18 Mismatch Loss (ML)

It is a measure of loss of power due to VSWR. It is related to the reflection co-efficient 'r' by the formula:

$$ML = -10 \log_{10} (1 - r^2)\ \text{dB}$$

4 ESSENTIAL PROPERTIES OF RECEIVING ANTENNAS

4.0 To ensure uniformity, and conformity with standardized specifications for antenna construction and performance, the following properties shall be included, where necessary, in specifications sheets.

4.1 Electrical Characteristics

4.1.1 *Resistive Load*

NOTE — This will be equal to the nominal characteristics impedance of the antenna transmission line.

4.1.2 *Bandwidth*

4.1.2.1 *Gain bandwidth*

4.1.2.2 *Directivity protection bandwidth*

4.1.2.3 *Impedance bandwidth*

4.1.2.4 *Gross-polarization protection bandwidth*

4.1.2.5 *Operating bandwidth*

4.1.3 *Directivity Protection*

4.1.4 *Cross-polarization Protection*

4.1.5 *Bandwidth*

4.1.6 *Reflection Co-efficient (or SWR or RLR)*

4.1.7 *Gain*

4.2 Mechanical Characteristics and Environmental Tests

4.2.1 *Wind Load*

4.2.2 *Wind Load with ICE*

4.2.3 *Ice Load*

4.2.4 *Mass (Assembled)*

4.2.5 *Mass (Shipping)*

4.2.6 *Dimensions*

4.2.7 *Environmental Tests*

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Indian Standard

ANTENNAS FOR THE RECEPTION OF SOUND AND TELEVISION BROADCASTING IN THE FREQUENCY RANGE 30 MHz TO 1 GHz — SPECIFICATION

PART 1 METHODS OF MEASUREMENT

Section 2 Methods of Tests of Electrical Performance Parameters

1 SCOPE

1.1 This standard (Part 1/Sec 2) applies to linearly polarized antennas for domestic use in the frequency range 30 MHz to 1 GHz.

2 REFERENCES

The Indian Standard IS 9793 (Part 1/Sec 1) : 1992 is a necessary adjuncts to this standard.

3 TEST METHODS

3.1 Reflection Coefficient

For most purposes, either the magnitude of the reflection coefficient or the standing wave ratio as a function of frequency for the range for which the antenna has been designed, will give sufficient information.

The one may be derived from the other or they may be independently determined from the antenna impedance either by calculation or by reading a smith impedance chart. The same precautions as indicated in **4.2** shall be taken into account.

The reflection coefficient can be calculated from measurements made by means of, for example, a slotted line, a frequency sweep method or a reflectometer method.

3.1.1 *Graphical Presentation*

The magnitude of the reflection coefficient or the standing wave ratio (SWR) or return loss ratio (RLR) shall be given as a function of frequency, the measured points being clearly indicated. The specified resistive load for which the antenna has been designed shall be stated.

3.2 Gain

Gain shall be expressed as defined in **3.2** of IS 9793 (Part 1/Sec 1) : 1992 and calculated from measurements made on size defined in **4.1**.

By the law of reciprocity, an antenna (other than an active receiving antenna will exhibit equivalent characteristics whether it be tested as a receiving or as a transmitting antenna. Either method may be used when measuring gain and directivity.

Gain shall be measured by either the substitution method, **3.2.1** (a) and (b), or by the reciprocity (identical antennas) methods, **3.2.2**.

3.2.1 *Gain Measurements by the Substitution Method*:

a) The antenna together with its mounting system, shall be placed on a site as indicated in **4** and exposed to an incident plane electromagnetic wave, having a polarization corresponding to the design of the antenna. The antenna output power delivered to the specified resistive load shall be compared with the power from a substituted reference dipole or transfer standard antenna; and

b) The antenna, together with its mounting system, shall be placed on a site as indicated in **4** and connected to a radio frequency source with an impedance equal to the terminals of this antenna, to produce a certain field strength at a distant receiving antenna, shall be compared with the power which must be supplied to a reference dipole or transfer standard antenna to produce the same field strength at the same distant receiving antenna.

In using the above methods (a) or (b) a resonant half-wave dipole will normally be used as a reference antenna in measuring gain, but it is frequently necessary to use a more directional antenna and this has been defined in **3.11** of Sec 1. A transfer standard antenna must have accurately known and consistently reproducible gain, directivity and cross-polarization characteristics. It must be completely specified in dimensional working drawings, with full mechanical specification to permit it to be reproducibly constructed whenever required.

Where an unbalanced transmission system is used, a suitable balance to unbalance transformation shall be made between the dipole and the transmission system; the transformation loss shall be taken into account.

The magnitude of the reflection coefficient of the reference antenna to the transmission system shall not exceed 0·1 at the measuring frequencies.

3.2.2 *Gain Measurement by the Reciprocity Method*

Two identical antennas of the type to be tested are necessary. One is used as the transmitting antenna and the other as the receiving antenna. Each aerial is mounted with its designed mounting system on a mast as described in **5.1**. During each measurement both antennas are at the same height above the ground, facing each other.

With the following notation:

As = the measured loss, in decibels;

Gi = the gain, in decibels, relative to an isotropic antenna;

d = the distance between the phase centres of the two antennas in metre;

λ = the wavelength corresponding to the measuring frequency in metres;

Gd = the gain, in decibels, relative to a half-wave dipole.

it can be shown that, provided the influence of ground reflections is negligible the measured loss between these two antennas is:

$$As = \left[20 \log \frac{4 \pi d}{\lambda} - 2\,Gi \right] \text{dB}$$

In practice, d can be assumed to be approximately equal to the distance between the feed-points of the two antennas. The gain relative to an isotropic antenna can therefore be evaluated from a loss measurement as follows:

$$Gi = \left[10 \log \frac{4 \pi d}{\lambda} - \frac{As}{2} \right] \text{dB}$$

Relative to a half-wave dipole, the gain will be:

$$Gd = \left[10 \log \frac{4 \pi d}{\lambda} - \frac{As}{2} - 2{\cdot}15 \right] \text{dB}$$

3.2.3 *Graphical Presentation*

Gain shall be presented in graphical form as a gain-frequency plot in the bandwidth of interest.

Any discrete measuring frequencies shall be clearly indicated on the graph, and the specified resistive load shall be stated.

The type and location of the reference antenna used in the measurement shall be stated on the graph.

The gain, as defined in 3.2 of Sec 1, shall be determined using a low-loss half-wave dipole as the reference, and shall be expressed in decibels.

NOTE — If by agreement between the manufacturer and the purchaser the gain is expressed, as indicated in the Note to 3.2 of Sec 1, in any other way, or using any other reference standard, or in reference to any directions of azimuth other than that of the main lobe, these facts shall be clearly stated on the graph and in the performance data sheet.

3.3 Directive Pattern

The measurement of directivity pattern shall be made on a site as specified in **4.1** in a uniform electromagnetic field, with polarization corresponding to that of the antenna during measurement.

3.3.1 *Graphical Presentation*

The directivity pattern may be presented as a polar diagram, using a decibel scale relative to maximum measured voltage. However, a linear voltage scale can be used, and in either case the pattern can be displayed in cartesian co-ordinates if required. The measured points shall be clearly indicated on the graph, down to the specified percentage of the main lobe, the percentage being stated.

When a continuous plot has been made, this shall be stated.

The measuring frequency and the orientation of the aerial with respect to the directivity pattern shall be clearly indicated on the diagram.

3.4 Directivity Protection

The directivity protection, as detailed in 3.3 of IS 9793 (Part 1/Sec 1) : 1992 shall be determined from the directivity pattern made for the frequency range specified in 3.6.2 of IS 9793 (Part 1/Sec 1) : 1992.

3.5 Cross-Polarization Protection

In measurements on cross-polarization protection, the orthogonal component of radiation from the transmitting antenna is significant and cannot be ignored.

Measuring procedures for cross-polarization protection, both in the direction of maximum gain, and as a cross-polarization directivity protection pattern for other directions of azimuth are considered in 5.3.

3.6 Impedance

The impedance of the antenna together with its mounting system may be measured by any suitable method directly or indirectly. Baluns may be needed when dealing with symmetrical antennas.

3.6.1 *Graphical Presentation*

The impedance of the antenna shall preferably be plotted on a Smith impedance chart with the frequency parameter, the measured points being clearly indicated.

This impedance shall be referred to the specified resistive load for which the antenna has been designed.

3.7 Feeder Pick-up Measurements

Under consideration.

NOTE — It is recommended that coaxial cables be connected to antenna terminal devices through a balun in order to minimize feeder pick-up.

4 MEASURING SITE

A suitable measuring site shall be of sufficient size and have surroundings which are substantially free from reflecting objects. It shall be noted that the dimensions of the site will be comparatively large when measurements are to be made at the lower frequencies and when high gain or physically large antennas are being tested.

4.1 Gain and Directivity Pattern Measurement

The following applies to those measurements of gain and directivity where the antenna to be measured is used as a receiving antenna.

In order to avoid errors in the measurements due to excessive variations in phase and amplitude in the space occupied by the antenna under test, the minimum distance between the antennas shall be determined from one of the two following requirements:

a) The variation in phase at the measuring site, in a plane perpendicular to the direction of propagation, occurring across a distance equal to the greatest physical dimension of the antenna under measurement, shall not exceed $\pi/8$ radians. To achieve this requirement, the distance between the two antennas shall be at least $2 (b_1^2 + b_2^2)/\lambda$, where b_1 and b_2 are the largest dimensions of the transmitting and receiving antennas respectively and λ is the wavelength; and

b) The swept volume occupied by the antenna when its mast is rotated shall be extended by at least one half wavelength in all directions and explored by a probe dipole not longer than one half wavelength and oriented for the polarization in use.

The requirement which specifies the greater distance shall be met.

The magnitude of the electromagnetic field shall be maintained constant within ± 1 dB at frequencies below 300 MHz and within ± 0·5 dB at frequencies above 300 MHz over this swept volume.

NOTE — Care shall be taken during this probing to ensure that the dipole is kept perpendicular to the direction of transmission and that the influence of cables and apparatus on the measurements is kept to a minimum.

The variation in observed signal level shall always be stated on gain and directivity graphs; this could be done, as an example, by plotting on a graph the signal strength as a function of the height of the antenna.

In this graph, a straight line parallel to the abscissa may be drawn, representing the average value.

Fig. 1 gives two examples of curves which may be obtained:

a) for the influence of the ground reflection being noticeable; and

b) for the influence of the ground reflection being hardly noticeable over a certain part of the curve.

NOTE — Errors may also be caused by residual cross-polarization or be due to interaction between the antenna and its transmission line. Care should be taken to keep these effects to a minimum.

The ratio of response of the antenna under test to the direct wave and to the ground-reflected wave shall not exceed the corresponding ratio for the reference antenna by more than 0·5 dB for horizontal polarization and 1 dB for vertical polarization. The angle between the direct and ground-reflected waves shall therefore be small enough to fulfil this condition, unless the following measures have been taken in order to reduce the ground-reflected wave:

a) the use of transmitting antenna with high directivity in a vertical plane;

b) the use of diffracting fences, between the transmitting antenna and the receiving antenna;

c) the use of an angle of incidence at the ground corresponding to the preudo-Brewster angle, in the case of vertical polarization; this angle is normally between 10° and 17°; and

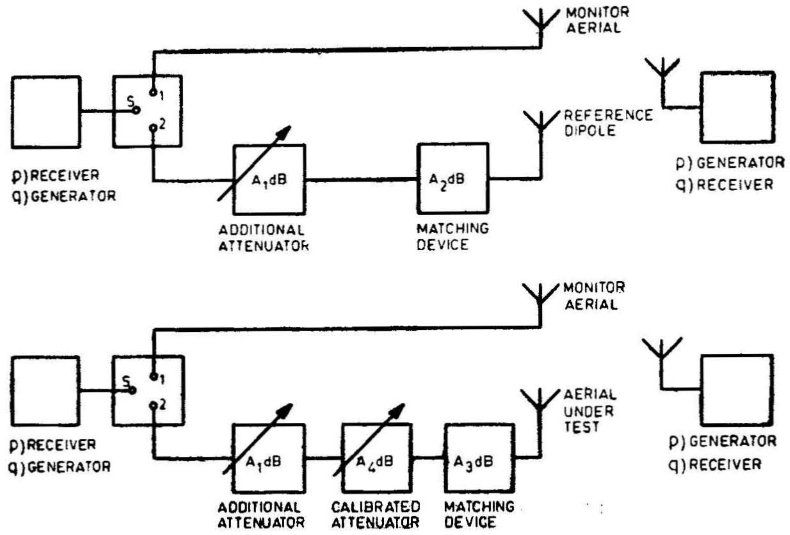
d) the use of a slant range when the source antenna is placed near the ground and the test antenna is elevated.

When directivity patterns are to be measured, it will also be advantageous to use a transmitting antenna which has a high directivity in a horizontal plane in order to prevent the influence of reflections from surrounding objects.

4.2 Impedance and Reflection Coefficient Measurement

To minimize influence large reflecting objects, including ground, on the impedance of the antenna, the distance from any point of the antenna under measurement at an angle 0 to those objects shall be not less than:

$$C_1 \,.\, G \,.\, e^2\theta \,.\, \lambda \text{ or } C_2 \,.\, b$$



Measuring arrangement:

Without altering the additional attenuator, the calibrated attenuator shall be adjusted for equal receiver input voltage in both positions of the switch ***S***.

The gain is equal to $G = (A_4 + A_3 - A_2)\ dB$.

FIG. 1 EXAMPLE OF CIRCUIT ARRANGEMENT FOR GAIN MEASUREMENTS, WITH THE AERIAL UNDER TEST USED AS A RECEIVING AERIAL, DISPOSITION p), OR AS A TRANSMITTING AERIAL, DISPOSITION q)

whichever is the greater.

In these formulae:

G = the gain, expressed as a numerical ratio, of the antenna under measurement, relative to a half-wave dipole

θ = the angular displacement from the direction of the main lobe

$e\theta$ = the ratio between the induced voltage at angle θ/to the induced voltage at $\theta = 0$ which is the direction of the main lobe

λ = the wavelength in metres

b = the largest dimensions of the antenna under measurement, in metres

C_1 and C_2 are constants which depend on the accuracy desired.

Table 1 indicates the values for C_1 and C_2, if the percentage of error, arising from the presence of large reflecting objects, is not to exceed the value specified in the first column.

Table 1 Values of Constants C_1 and C_2

Required Accuracy (1) (Percent)	C_1 (2)	C_2 (3)
10	1·2	0·5
5	2·4	0·8
3	4·0	1·3

NOTES

1 These values are not valid when resonance effects, caused by multiple surface reflections, occur in the space around the antenna.

2 Care shall be taken to ensure that small reflecting objects such as measuring instruments are placed far enough from the antenna under test.

3 The transmission line, including the mounting system, shall be placed as specified by the manufacturer. Where no position is specified, the transmission line and the mounting system shall be disposed in a manner which minimizes interaction with the antenna.

5 MEASURING PROCEDURES

5.1 Gain

5.1.1 *Method A*

Dipole and transfer standard antennas used in gain measurements shall preferably be placed with their feed points in the same position as the feed point of the antenna under measurement.

When this is impracticable, a more suitable point may be chosen, but in all cases the point chosen shall be stated in the results of the measurement.

Whenever possible, the same transmission line system shall be used for the test antenna and the reference antenna. The attenuation of the transmission line system used shall be taken into account at each measuring frequency. *See* also Note 3 of **4.2.**

To ensure system stability during measurement:

a) when using the antenna under test for receiving, a receiving monitor antenna shall be used and placed in such a position that it does not alter the electromagnetic field around the antenna under test (*see* Fig. 2); and

b) when using the antenna under test for transmitting, a transmitting monitor antenna shall be used and placed in such a position that it does not alter the electromagnetic field of the antenna under test (*see* Fig. 2).

The antenna to be measured shall be connected to the measuring device or to the r. f. generator by means of a transmission system, matched at the antenna terminals for a reflection coefficient, of a magnitude less than 0·1 (or return loss of − 20 dB) referred to the specified resistive load.

In making measurements of gain or cross-polarization protection by the reciprocity method, using a pair of identical antennas, the following additional precautions shall be observed in preparing the measuring site, and the antennas for test.

The antenna to be measured shall be mounted with their designed mounting on two identical (for example telescopic) masts and facing each other. The heights of the antennas above the ground shall be adjustable and calibrated so that both antennas are at the same height above the ground. The minimum height above the ground shall be least 2λ.

The distance d between the two antennas shall be known and shall be at least 3λ or $4b^2$, whichever gives the largest value; 'b' is the largest dimension of the antenna and λ the wavelength corresponding to the measuring frequency. Distances and heights shall be stated with the results, whilst the chosen centre shall be shown in the relevant drawing of the antenna.

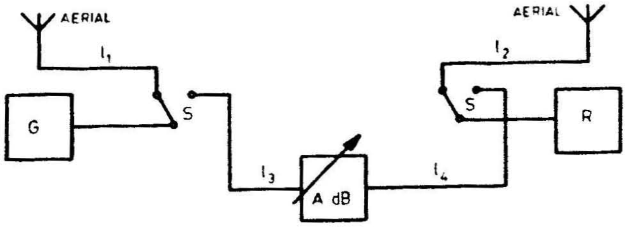
The influence of ground reflection on gain measuring may be assessed by varying the height of the antennas above the ground simultaneously from a minimum value of 2λ and observing the relative voltage variation, corresponding to signal strength, as a function of the height of the antennas.

The chosen height shall be regarded as satisfactory if these variations are within ± 1 dB at frequencies below 300 MHz and within ±0·5 dB at frequencies above 300 MHz.

In making gain measurements by the reciprocity method using two identical antennas, the loss between the two antennas may be measured in various ways depending on the available measuring apparatus.

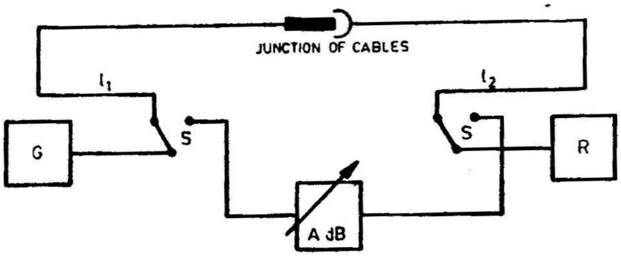
a) In Fig. 3, the total attenuation including attenuator insertion lost must be known. The antenna cables with lengths l_1, l_2, l_3 and l_4 are of the same type. $l_1 + l_2 = l_3 + l_4$ so that their attenuation in the two switch positions is the same. For both positions of the switches, the impedance offered to both antennas shall have a value which gives rise to a reflection coefficient with magnitude less than 0·1 relative to the specified resistive load for which the antenna has been designed. *R* is a receiver with a signal strength indicator and *G* a signal generator. Both are tuned to the frequency at which the gain is to be measured. It is necessary to match the impedance of *R* and *G* and both sides of attenuator *A* to the cables, the magnitude of the reflection coefficient being less than 0·1. The attenuator *A* is adjusted until the receiver indicator reads the same in both positions of the switches *S*. The attenuation as read on the attenuator scale and expressed in decibels is equal to the measured loss.

b) In Fig. 4 and 5, the total attenuation in the circuits need not be known. Also the lengths of the cables l_1 and l_2 are not critical because they have no influence on the measurement. However the matching requirements are the same as under (a).



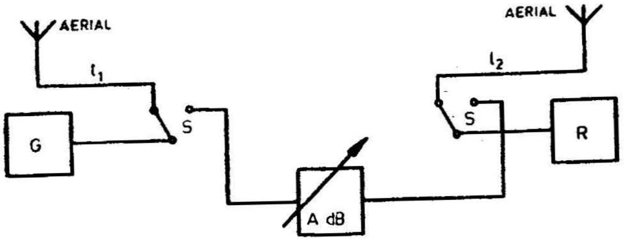
G = Signal Generator
R = Receiver
A = Attenuator
S = Radio frequency switches

FIG. 2 SCHEMATIC CIRCUIT ARRANGEMENT FOR MEASURING SYSTEM LOSS



G = Signal Generator
R = Receiver
A = Attenuator
S = Radio-frequency switches

FIG. 3 SCHEMATIC CIRCUIT ARRANGEMENT FOR MEASURING CABLE ATTENUATION



G = Signal Generator
R = Receiver
A = Attenuator
S = Radio-frequency switches

FIG. 4 SCHEMATIC CIRCUIT ARRANGEMENT FOR MEASURING SYSTEM LOSS

First the antenna ends of the two cables are connected as in Fig. 4. For each measuring frequency the attenuator A is adjusted until the receiver R indicates the same output for both positions of the switches S. Suppose this attenuator reads A_1 dB.

The antennas are then connected to the cables as in Fig. 5 and the attenuator A is again adjusted until the receiver R indicates the same output for both positions of the switches S. Suppose the attenuator reads A_1 dB.

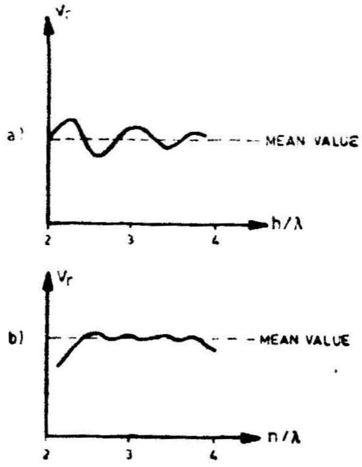


FIG. 5 VARIATION OF THE VOLTAGE V_r WITH THE RELATIVE ANTENNA (AERIAL) HEIGHT h/λ

The antennas are then connected to the cables as in Fig. 5 and the attenuator A is again adjusted until the receiver R indicates the same output for both positions of the switches. Suppose the attenuator setting reads A_2 dB, then the measured loss is:

$$As = (A_2 - A_1) \text{ dB}$$

5.1.2 *Method B*

Calibration of Gain Standards on a Free-Space Antenna Range. Absolute-gain measurements are based upon the Friis transmission formula, which states that for a two-antenna system as shown in Fig. 6, the power received at a matched load connected to the receiving antenna is given by:

$$P_r = P_0 \, G_A \, G_B \frac{(\lambda)^2}{(4R)}$$

where P_r is the power received, P is the power accepted by the transmitting antenna, G_A is the power gain of the transmitting antenna, and G_B is the power gain of the receiving antenna. R is the distance between transmitting and receiving antenna with the same units as that of wavelength. This form of the transmission formulae implicitly assumes that the antennas are polarization matched for their prescribed orientations and that the separation between the antennas is such that far-field conditions prevail.

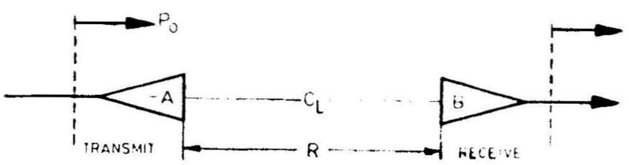


FIG. 6 TWO-ANTENNA SYSTEM ILLUSTRATING THE FRIIS TRANSMISSION FORMULA

The Friis transmission formula can be written in logarithmic form, from which the sum of the gains, in decibels, of the two antennas can be written as:

$$(G_A)\,\text{dB} + (G_B)\,\text{dB} = 20 \log \frac{(4 \pi R)}{(\lambda)} - 10 \log \frac{(P_0)}{(P_r)}$$

If the two antennas are identical, it follows that their gains are equal so that:

$$(G_A)\,\text{dB} + (G_B)\,\text{dB} = \tfrac{1}{2}\, 20 \log \frac{(4 \pi R)}{(\lambda)} - 10 \log \frac{(P_0)}{(P_r)}$$

The procedure in determining the power gain of the antennas is to measure R, and 10 log P_0/P_r and then compute (G_A) dB. Since two indentical antennas are required, this method is referred to as the two-antenna method. If antennas A and B are not identical, a third antenna is required to determine the gains.

For the three-antenna method three sets of measurements are performed using all combinations of three antennas. The result is a set of three simultaneous equations of the form:

$$(G_A)\,\text{dB} + (G_B)\,\text{dB} = 20 \log \frac{(4 \pi R)}{(\lambda)} - 10 \log \frac{(P_0)}{(P_r)\,AB}$$

$$(G_A)\,\text{dB} + (G_C)\,\text{dB} = 20 \log \frac{(4 \pi R)}{(\lambda)} - 10 \log \frac{(P_0)}{(P_r)\,AC}$$

$$(G_A)\,\text{dB} + (G_O)\,\text{dB} = 20 \log \frac{(4 \pi R)}{(\lambda)} - 10 \log \frac{(P_0)}{(P_r)\,BC}$$

From these equations all three gains can be determined.

The block diagram of Fig. 7 is typical of the instrumentation required for the measurement of gain using the two-antenna or three-antenna methods. The instrumentation shall be highly stable with the source producing a signal sinusoidal frequency. With reference to Fig. 7, the procedure is to first calibrate the coupling network between the source and the transmitting antenna so that the power measured at the transmit test point can be accurately related to the power into antenna A. Then all components of the system are impedance matched using tuners. The two antennas are separated so that far-field conditions prevail and bore-sighted so that they are properly aligned and oriented.

The attenuator of the coupling network is adjusted so that the power level at the transmit test point is the same as that at the receive test point. From the calibration of the coupling network the relative power level P_0/P_r can be determined.

If the gains of broad-band antennas are to be measured, it may be necessary to use the swept-frequency technique. Both the two-antenna and three antenna methods can be employed. It should be noted that it is not possible to match all the components over a band of frequencies. Therefore, the impedances or reflection coefficients of all components shall be measured. The swept-frequency technique should be used for those measurements.

5.2 Directivity Pattern

For reasons of convenience, the antenna, together with its mounting system, shall be oriented in such a way that the plane in which the directivity pattern is to be measured is horizontal so that the antenna can be rotated around a vertical axis.

When the antenna is measured as a receiving antenna, the output voltage or current originating from an incident plane electromagnetic wave shall be measured as a function of the angle of rotation.

When the antenna is measured as a transmitting antenna, the field strength at a distant receiving antenna shall be measured as a function of the angle of rotation of the transmitting aerial. The receiving antenna shall be orientated to measure the appropriately polarized radiation from the antenna under test.

Sufficient points shall be taken to define all those parts of the directivity pattern where the response voltage is greater than a specified percentage of the main lobe.

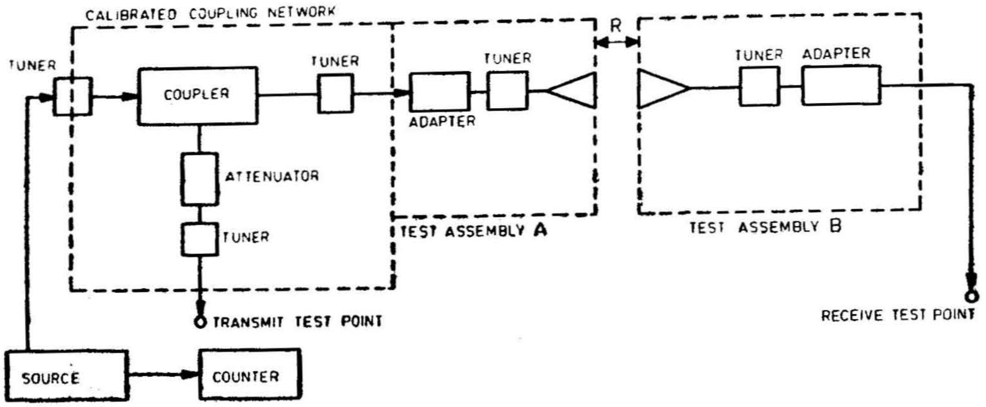


FIG. 7 TYPICAL INSTRUMENTATION FOR TWO-ANTENNA AND THREE-ANTENNA METHODS OF POWER-GAIN MEASUREMENT

5.3 Cross Polarization Protection

5.3.1 *Forward Protection*

In this measurement the test site shall be substantially reflection free, and precautions shall be taken to ensure that the position of the feeder cable does not change relative to any antenna element when the antenna is rotated to an orthogonal polarization plane.

Both antennas shall, therefore, be end-mounted with the feeder cable taken preferably through, or closely adjacent to the antenna boom and the supporting mast shall be sufficiently far behind the antenna to have negligible influence its performance in any plane of polarization.

If the antenna is too large to be supported from its rear end, then an insulating support mast may be used, moulded so as to have minimal capacitive effect on any part of the antenna. The feeder cable shall still be taken from the rear of the antenna as indicated above.

Measurement of cross polarization protection in the forward or main lobe direction (which is the direction of the axis of rotation for this measurement) may be made by using two identical antennas of the type being tested.

One is used as the transmitting antenna and the other as the receiving antenna and they shall be mounted as described in **5.1**.

The test site shall meet all the requirements detailed in **5.1** with particular care being taken to match and balance energy transfer between antenna and feeder.

The precautions detailed in **5.1** for this type of measurement shall also be taken.

The antennas shall be mounted with the designed planes of polarization being coincident, then the receiving antenna shall be slightly rotated about its axis to maximize the power transfer. This angle of rotation shall be indicated with θ, and shall be considered as twice of the angular distance between the designed plane of polarization and that of maximum radiation. This value of θ may also be checked with a suitable probe of known polarization axes used as receiving antenna.

The signal level at the receiving antenna terminals shall be measured and indicated with V_p.

The transmitting antenna shall then be rotated through 90° about its axis, so that it is transmitting an orthogonally poloarized wave. The signal level shall be measured and indicated with V_x.

The value of cross polarization protection C (dB), of the antenna, when $\theta = 0$ can be obtained from the numerical ratio V_x/V_p.

C_1 from the following equation :

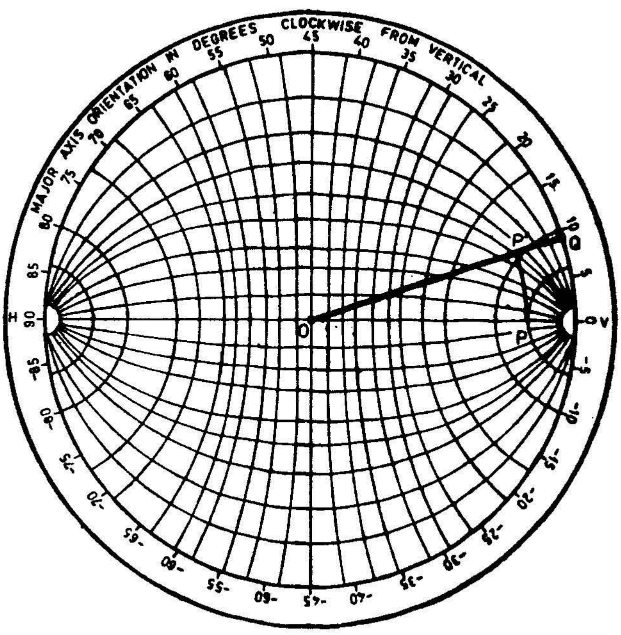
$$(1)\quad C\text{dB} = 20 \log_{10} \frac{1 - \sqrt{1 - C_1^2}}{C_1}$$

For high values of C_1 equation (1) can be simplified as follows:

$$(2)\quad C\text{dB} = C_1\,\text{dB} + 6$$

NOTE — As an example, if the measured ratio C_1 is 10 dB, the value of C is 15·8 dB, while the approximate formula gives 16 dB.

When θ is different from O, this value shall be corrected to take into account the difference between the designed direct-polarized plane and the true direct-polarized plane. This may be done by using the polarization efficiency equation applied to this particular case, or, more simply, via a suitable transformation chart (Fig. 8), which shall be used as follows:



Phase in parentheses is for predominantly left hand sense.

FIG. 8 POLARIZATION CHART

1) Enter C (in decibels) on the horizontal diameter on the graph (Point P).
2) Enter $\theta/2$ on the circumference and draw a radius from the centre (OQ).
3) Find a point P' on OQ such as $OP = OP'$.
4) P' is on a curve $C = C_0$; C will be the required value of cross polarization protection.

An example is shown in Fig. 8 in which the value $C = 20$ dB is corrected to $C_0 = 15$ dB, because of a tilt angle of 9°.

5.3.2 *Protection in Other Directions of Azimuth*

The transmitting antenna used in measuring forward cross-polarization protection is left in the same position and with the same mounting as in **5.3.1**, but is now used as a reference antenna with a predetermined value of forward cross-polarization protection C_0 obtained in the above measurement.

The receiving antenna is now mounted as it would be in a typical installation, as recommended by the manufacturer with the feeder and the mast in the positions they would occupy in practice.

The antenna is now rotated at a sufficient number of angular positions O_2 to enable a cross-polarization protection directivity pattern to be obtained.

In each position the receiving antenna shall be rotated about its axis of an angle θ for maximum power transfer. This angle may be easily obtained by rotating first the source antenna for minimum power transfer, and then rotating it through 180°.

Signal level measurements shall be made in this plane and with the receiving antenna rotated through 180° about its axis; the ratio of these signals will be indicated with $C_1(O)$.

If θ is the difference between the designed polarization plane and the plane containing the major axis of the polarization ellipse of the transmitting antenna, it will be assumed $\theta = \theta_t - \theta_r$.

When $\theta = O$, the cross polarization protection can be determined from the ratio of the measured signal level C_1 by using the following formula:

$$C(O) = \frac{C_1(O) - C_0}{1 - C_1(O)C_0}$$

In practice, since $C_1 . C_0 < < 1$, the cross polarized level will be the difference between the measured value and that of the transmitting antenna.

When $\theta = O$, the value of $C(O)$ given by (3) may be corrected by the same procedure outlined at the end of **5.3.1**.

6 REFERENCE ANTENNAS

Under consideration.

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Indian Standard

ANTENNAS FOR THE RECEPTION OF SOUND AND TELEVISION BROADCASTING IN THE FREQUENCY RANGE 30 MHz TO 1 GHz — SPECIFICATION

PART 1 METHODS OF MEASUREMENTS

Section 3 Methods of Tests for Mechanical Properties and Environmental Tests

(First Revision)

1 SCOPE

1.1 This standard (Part 1/Sec 3) applies to linearly polarized antennas for domestic use, for the reception of sound and television broadcasting in the frequency range 30 MHz to 1 GHz.

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
9000	Basic environmental testing procedures for electronic and electrical items:
(Part 8) : 1981	Part 8 Vibration (sinusoidal) test
(Part 11) : 1983	Part 11 Salt mist test
(Part 19/Sec 1) : 1986	Part 19 Test U : Robustness of terminations and integral mounting devices, Section 1 Test Ua1 : Tensile (*first revision*)
(Part 19/Sec 2) : 1986	Part 19 Test U : Robustness of terminations and integral mounting devices, Section 2 Test Ua2 : Bending (*first revision*)
(Part 19/Sec 3) : 1986	Part 19 Test U : Robustness of terminations and integral mounting devices, Section 3 Test Ub : Bending (*first revision*)
(Part 26) : 1980	Part 26 Sulphur dioxide test for contacts and connections
9793 (Part 1/Sec 1) : 1992	Antennas for the reception of sound and television broadcasting in the frequency range 30 MHz to 1 GHz : Part 1 Methods of measurement, Section 1 Electrical and mechanical characteristics

3 MECHANICAL CALCULATIONS

3.1 Dynamic and Static Loading

3.1.1 *Wind Load*

Antenna wind load is defined in **3.9** of IS 9793 (Part 1/Sec 1) : 1992. It shall be calculated from the area exposed to the wind, measured in square metres, of the assembly of all elements and supporting structural components of the antenna array, excluding the mast, in the vertical plane in which this area is maximum. An example of the area is the projection on a vertical plane prependicular to the wind direction.

Appropriate area correction coefficients for the calculation of the area shall be applied as given in Table 1.

Table 1 Area Correction Coefficient

Cross Section	Area Correction Coefficient
(1)	(2)
Cylindrical or convex curves	1·02
Rectangular or square	1·55

The wind load shall be expressed in newtons as derived from the following formula:

$$W = C_1 \, . \, p \, . \, A_1 + C_2 \, . \, P \, . \, A_2 + \text{.......}$$

where C_1, C_2 etc, are the appropriate area correction coefficients for component areas. A_1, A_2 etc, measured in square metres and P is the wind pressure in pascals for the specified wind velocity.

NOTE — 1 pascal = 1 N/m².

Wind loading formulas are not a simple function of wind velocity because of turbulence and other non-linear phenomena.

The following equation gives a sufficiently close approximation for practical use in determining wind pressure:

$$P = 0{\cdot}65\ V^2$$

where P is measured in pascals and V in metres per second.

For the purpose of establishing mast loadings, the wind pressure at typical wind velocities, as indicated in Table 2 shall be given.

Table 2 Wind Pressure at Typical Wind Velocities

Wind Velocity		Approximate Wind-Pressure
m/s	km/h	Pa
45	162	1 300
35	126	800
30	108	585

Where the wind load from directions other than maximum is required, it shall be specified as agreed between the manufacturer and the user.

Where the moment on the supporting mast due to the wind load on the antenna is given in the relevant specification sheet, this shall be calculated in Nm.

3.1.2 *Wind Load in the Presence of Ice*

Where required, antenna wind load in the presence of ice shall be calculated and specified in the relevant specification sheet on the assumption that the ice coating is uniform on all antenna elements and components.

3.1.3 *Static Load (also Including Ice)*

Under consideration.

4 MECHANICAL MEASUREMENTS

4.2 Dynamic and Static Loading

Under consideration.

4.2 Terminal Device Robustness

To determine the ability of the antenna terminal device to withstand the direct axial and bending stresses likely to be applied during antenna installation or in service, the relevant tensile and bending tests of IS 9000 (Part 19/Sec 1 to 3) : 1986 shall be applied. The value of the loading force shall be 40 N. The terminals shall be checked after test as specified in **5.1.2.**

NOTE — In this context, terminal devices may be used for connecting impedance matching, or array phasing cables or for the main antenna down lead, as appropriate.

5 ENVIRONMENTAL TESTS

5.1 Vibration

Tests may be based where applicable on IS 9000 (Part 8) : 1981. The following test parameters have been successfully used for performance evaluation and are put forward as a guide; other parameters giving equivalent acceleration stresses may be adopted at discretion, but should be quantified in the relevant specification sheet.

5.1.1 *Low-Frequency High-Amplitude Vibration Test*

Frequency
Maximum component amplitude
Test duration

5.1.1.1 *Procedure*

The antenna under test is to be rigidly mounted on the vibration equipment. The input displacement is adjusted until the maximum amplitude of movement of some part of the antenna is under test reaches the specified value.

NOTE — This method will take into account the natural resonant frequency of any antenna component provided that, in setting up, the antenna is allowed to reach a dynamic equilibrium.

5.1.1.2 *Evaluation*

After the test, the antenna shall be examined visually. It should withstand the vibration test without any significant permanent component displacement and without any failure in any part.

5.1.2 *High-Frequency Low-Displacement Vibration Test*

Frequency
Maximum component amplitude
Test duration

5.1.2.1 *Procedure*

As described in **5.1.1.1.**

5.1.2.2 *Evaluation*

As described in **5.1.1.2.**

5.2 Atmospheric Environmental Protection

5.2.1 *Salt Mist Test*

To determine the resistance of an antenna to deterioration from salt mist, the test shall be applied as described in IS 9000 (Part 11) : 1983 Procedure 3 with the following variations: three spraying periods of 2 h duration, each followed by a storage periods of 22 h duration in the chamber, shall be applied. A temperature of 35 ± 2°C shall be used for both spraying and storage. The relative humidity during storage shall be 90 to 95 percent.

Where the antenna is physically too large to be tested in an available chamber, standard production parts whose length alone is reduced as required to accommodate the antenna in the test chamber may be subjected to the salt mist test mentioned above. In case the antenna has any active element, the same should be subjected to the salt mist test alongwith the standard parts. Evaluation shall be made by visual examination. In addition, the appropriate electrical measurements shall be carried out before and after the test on the active element for their performance.

5.2.2 *Industrial Atmosphere, Sulphur Dioxide Test*

The object of this test is to determine the resistance of electrical components and connections to an atmosphere containing sulphur dioxide and particularly to changes in electrical contact resistance in the circuits.

5.2.2.1 *Test chamber*

The test chamber shall comply with the requirement of IS 9000 (Part 26) : 1980.

5.2.2.2 *Conditioning atmosphere*

The composition of the atmosphere within the test chamber shall satisfy the following conditions:

Sulphur dioxide (SO_2) : 25 ± 5 × 10^{-6} (vol/vol)
Carbon dioxide (CO_2) : 4 500 ± 500 × 10^{-6} (vol/vol)
Temperature : 25 ± 2°C
Relative humidity : 75 ± 5 percent

5.2.2.3 *Test conditions*

The test duration shall be 21 days in the atmosphere as specified in **5.2.2.2**.

Reduced size models may be used as described in **5.2.1** if necessary, and evaluation shall be based on visual examination and by making appropriate electrical cantact resistance measurements on all electrical connections in the antenna array before and after the test.

5.2.3 *Weather Proofing*

A driving rain test shall be applied, as described in Annex A, to the antenna or to a model as described in **5.2.1**. The shower heads shall be located at a distance between 500 mm and 750 mm from the antenna component which is required to be weather-proof under this test.

Evaluation shall be as described in **A-5** of Annex A and in **5.1.1.2**, by visual examination and by carrying out any appropriate electrical tests before and after conditioning.

ANNEX A

(*Clause* 5.2.3)

DRIVING RAIN TEST

A-1 INITIAL MEASUREMENTS

A-1.1 The antennas shall be visually inspected and electrically and mechanically checked as required by the relevant specification. All sealing features shall be checked as to whether they have been mounted correctly.

A-2 PRE-CONDITIONING

A-2.1 Pre-conditioning of the antennas and seals shall be carried out if required by the relevant specification.

A-3 CONDITIONING

A-3.1 The antennas shall be subjected to a shower of water from eight shower heads. The water from four of the shower heads shall be directed downwards at an angle of 45°C at each of the four uppermost corners of the antenna under test. The water from the remaining four shower heads shall be directed horizontally to the most vulnerable spot of the area of each of the four sides as indicated by the relevant specification.

A-3.2 The shower heads shall be located at a distance of 500 mm to 750 mm from the corners or sides of the antenna under test or at the distance as required by the relevant specification.

A-3.3 The dimensions of the shower head shall be in accordance with Fig. 1 and this will provide a cone angle of approximately 35° (*see* Fig. 2).

NOTE — Use of this head will lead to water consumption of approximately 450 litres per hour with an overpressure of 20 N/cm².

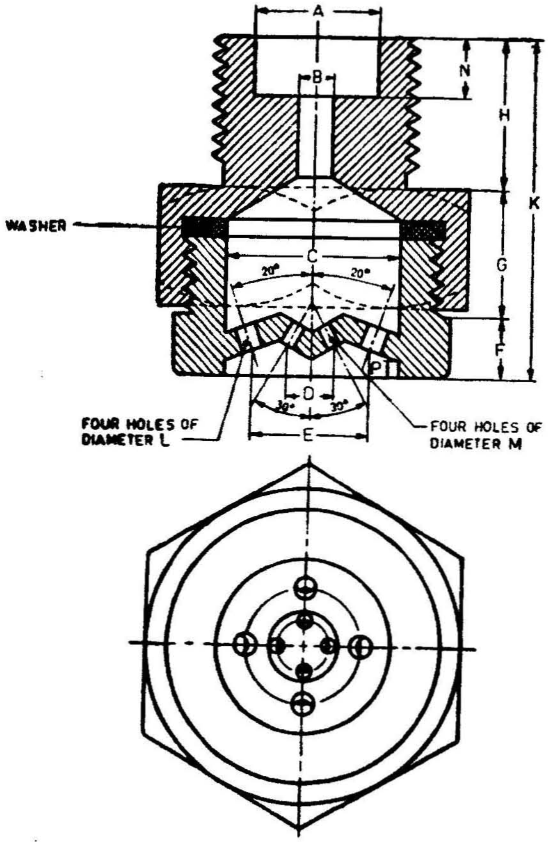
A-3.4 The antennas shall be exposed to the rain for a period of 1 h.

A-3.5 The antennas shall be subjected to the test in their normal mounting position, unless otherwise specified in the relevant specification.

A-3.6 If required by the relevant specification, the antennas shall be operating during conditioning.

A-4 RECOVERY

A-4.1 The external surfaces of the antennas shall be dried by wiping or by applying a blast of air at room temperature, unless otherwise specified by the relevant specification.



Angle of Cone 35° Approximately

Reference	*A*	*B*	*C*	*D*	*E*	*F*	*G*
mm	13·5	13·8	19·0	5·6	12·7	6·35	13·5
	H	*K*	*L*	*M*	*N*	*P*	
	15·9	35·7	2·3	1·6	6·3	1·6	

FIG. 1 DIMENSIONS OF SHOWER HEAD

A-5 FINAL MEASUREMENTS

A-5.1 The antennas shall be examined for undue penetration of water and shall be visually inspected and electrically and mechanically checked as required by the relevant specification.

The presence of the shower heads may modify the antenna performance; if any of the radio frequency tests are required by the specifications, the shower heads must be removed.

A-6 INFORMATION REQUIRED IN THE RELEVANT SPECIFICATION

A-6.1 Where this test is included in the relevant specification, the following details shall be given as far as they are applicable:

a) Electrical and mechanical checks prior to conditioning;

b) Pre-conditioning procedure;

c) Distance between shower heads and antenna during conditioning;

d) Mounting position during conditioning;

e) Operating conditions;

f) Electrical and mechanical checks after recovery;

g) Allowable limits of water penetration; and

h) Any deviation in procedure.

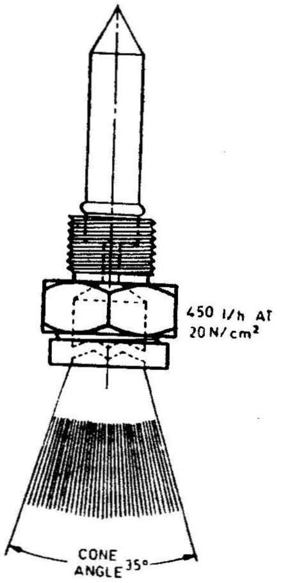


FIG. 2 CONE ANGLE

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